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13. ABSTRACT *(Maximum 200 words)*
IN ACCORDANCE WITH A DIRECTIVE FROM THE COLORADO DEPARTMENT OF HEALTH, THE REINJECTION WATER AT THE NORTH BOUNDARY OF RMA WILL BE SUBJECT TO EPA AND CDH DRINKING WATER STANDARDS. IN RESPONSE TO THIS DIRECTIVE, RUBEL AND HAGER WAS ENGAGED BY RMA TO PERFORM A FEASIBILITY STUDY DURING SEPTEMBER 1978. THE STUDY DOCUMENTED THAT USING THE ACTIVATED ALUMINA TREATMENT METHOD, THE EXCESS FLUORIDE CAN BE REMOVED FROM THE CARBON TREATED WATER AT THE REINJECTION SITE. AT THE CONCLUSION OF THE FEASIBILITY STUDY, IT WAS DETERMINED THAT FURTHER PILOT TESTING WOULD BE NECESSARY TO OPTIMIZE THE CAUSTIC REGENERATION PROCEDURE FOR MAXIMUM LONG-TERM ECONOMY. THEREFORE, THIS PILOT TEST PROGRAM WAS ESTABLISHED. THE FLUORIDE REMOVAL PILOT TEST RUNS HAVE DEMONSTRATED THAT A FULL SCALE FLUORIDE REMOVAL WATER TREATMENT PLANT, WITH RAW WATER PH ADJUSTMENT, CAN RELIABLY REMOVE 1700 GRAINS OF FLUORIDE PER CUBIC FOOT OF ACTIVATED ALUMINA. OPERATING TREATMENT COST PROJECTION FOR THE FULL SCALE PLANT IS 15/1000 GALLONS. CAPITAL COST ESTIMATE FOR THE 1000 GPM TREATMENT SYSTEM IS $270,000.

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WASTEWATER, COST, TREATMENT

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FINAL REPC...

ON

PILOT TEST PROGRAM

FOR

REMOVAL OF EXCESS FLUORIDE

FROM

ACTIVATED CARBON EFFLUENT

FOR

THE DEPARTMENT OF THE ARMY
ROCKY MOUNTAIN ARSENAL
(REF. CONTRACT #DAAA05-79-C-006)

By

Rubel and Hager, Inc.
4400 E. Broadway, Suite 710
Tucson, Arizona 85711

November 30, 1979

Copies

1 - 6: Carl G. Loven

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INTRODUCTION

In accordance with a directive from the Colorado Department of Health, the reinjection water at the north boundary of the Rocky Mountain Arsenal will be subject to drinking water standards established by the U. S. Environmental Protection Agency and the Colorado Department of Health. In addition to organic limitations for which purpose the granular activated carbon system was installed, there is also a specific limit of 2.4 mg/l of fluoride.

In response to this directive, this firm, Rubel and Hager, Inc. was engaged by the Rocky Mountain Arsenal to perform a feasibility study[1] during September 1978. The results of that study documented that using the activated alumina treatment method the excess fluoride can be removed from the carbon treated water at the reinjection site. That study, consisting of two complete treatment cycles including chemical regeneration, demonstrated the removal of fluoride from levels of 4-5 mg/l to an average of 1 mg/l. A capacity of more than 2,000 grains of fluoride per cubic foot of activated alumina was achieved in both cycles. That fluoride removal level is far below the maximum contaminant level requirement for fluoride of 2.4 mg/l established by the EPA and the Colorado Department of Health. At the conclusion of the feasibility study, it was determined that further pilot testing would be necessary to optimize the caustic regeneration procedure for maximum long term economy. Therefore, this pilot test program was established.

The purpose of this program was to determine whether there are any interferences present in the activated carbon effluent that may reduce the efficiency of the process. An optimum alumina regeneration process will be developed to minimize operating costs. The working capacity of the activated alumina along with chemical consumption upon which a full-scale plant can be designed will be determined.

TEST APPARATUS

The test apparatus is a fully assembled skid-mounted treatment system (see Figure 1 for Schematic Flow Diagram). The system is designed to treat the activated carbon effluent at the rate of 5 gpm at 50 psig maximum working pressure. There are two treatment vessels (fourteen-inch diameter by ninety six inches high) each contains 3.75 cubic feet of Alcoa (grade F-1, - 28+48 mesh) activated alumina. This manually operated system is piped to permit one treatment unit to perform design flow treatment individually, or two units can be operated in either series or parallel. The system contains 1" PVC schedule 80 threaded pipe and fittings with manually operated full port ball valves. Accessories for each treatment unit include pH sensors with panel mounted indicators at inlet and outlet, sample points at inlet and outlet, a pressure gauge, an air vent, a flow totalizer, injection points for acid and caustic, and an in-line static chemical mixer.

The system also includes a feed water pump, a caustic feed system, an acid feed system, a zeolite softener, and sample points. The caustic feed system includes one twelve gallon solution tank and one metering pump for 50% sodium hydroxide. The caustic is employed during regeneration only; therefore, one pump serves both treatment units. The acid feed system includes one fifty gallon solution tank and two metering pumps for dilute sulfuric acid. One acid pump is required for pH adjustment for each treatment unit. The zeolite softener is an optional feature which can be used to pretreat raw water during caustic regeneration. There are also provisions for adding other pretreatment equipment, or additional treatment units.

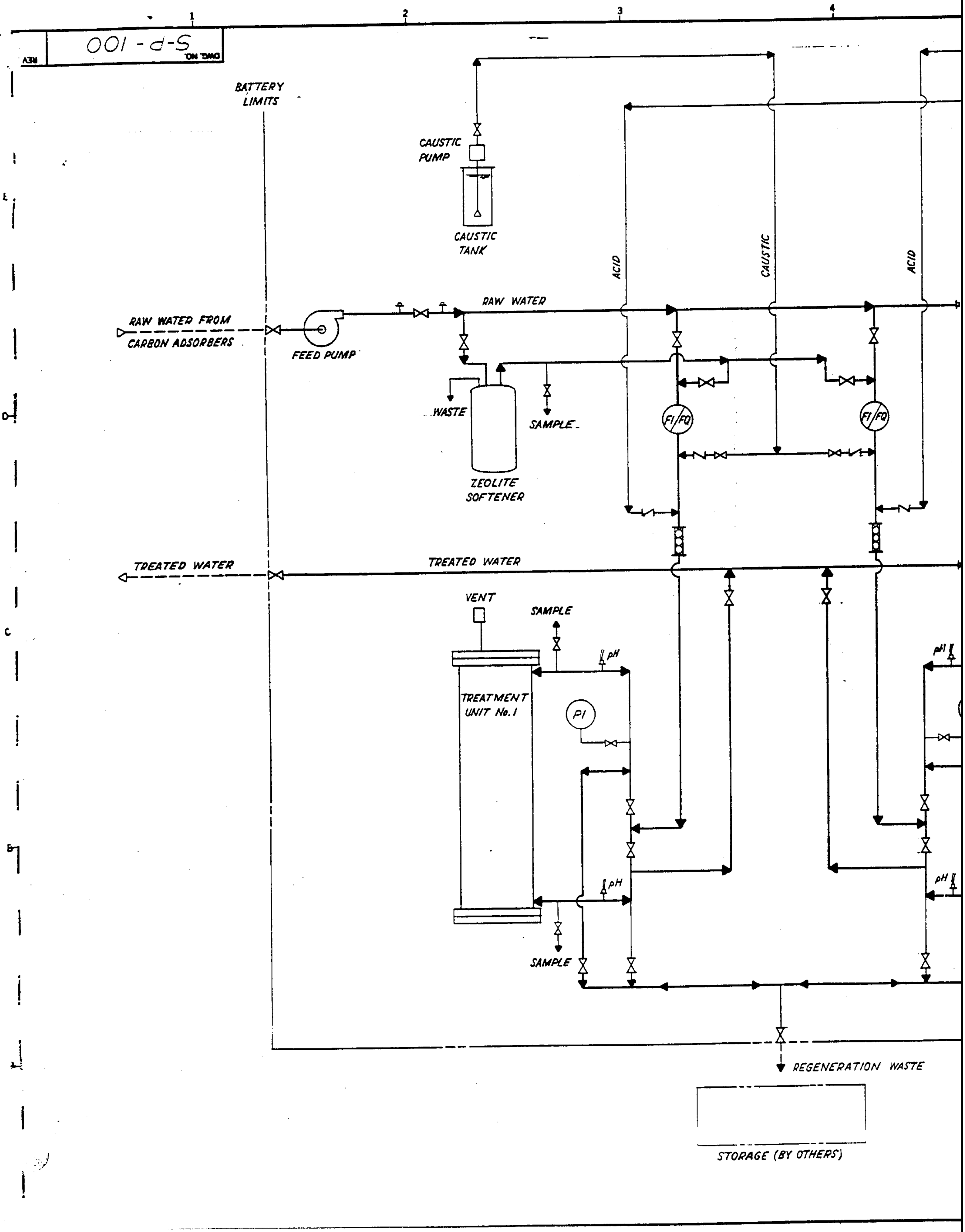
The entire treatment system is mounted on a steel skid (six feet wide by ten feet long) which is elevated approximately eighteen inches above the floor. The skid is located adjacent to the activated carbon system in the north boundary treatment building. Raw water is piped from the carbon adsorbers to the feed water pump suction. The treated water is piped to a designated discharge point. Regeneration wastewater is collected in 50 gallon drums for analysis and waste treatment process development.

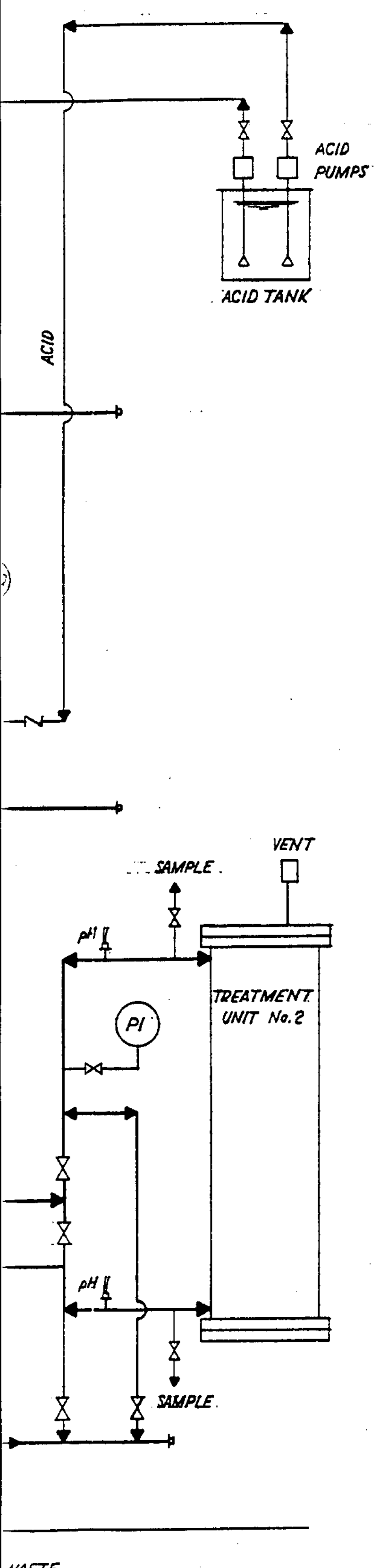
TEST PROGRAM

The scope of the test program for the 5 gpm pilot included six complete treatment cycles. Each cycle consisted of a treatment run through exhaustion of the treatment bed followed by a chemical regeneration.

Treatment Unit No. 1 was designated as the primary treatment unit; Treatment Unit No. 2 was designated as the standby treatment unit. All testing took place in the primary unit.

Upon completion of the installation of the pilot plant test


DWG. NO.
S-P-100
REV
BATTERY LIMITS
CAUSTIC PUMP
CAUSTIC TANK
ACID
CAUSTIC
ACID
RAW WATER FROM CARBON ADSORBERS
FEED PUMP
RAW WATER
WASTE
SAMPLE
ZEOLITE SOFTENER
FI/FQ
FI/FQ
TREATED WATER
TREATED WATER
VENT
SAMPLE
pH
TREATMENT UNIT No. 1
PI
pH
SAMPLE
pH
pH
REGENERATION WASTE
STORAGE (BY OTHERS)



LEGEND

- FEED PUMP
- IN LINE STATIC MIXER
- INJECTION BALL CHECK
- SHUT OFF VALVE
- PRESSURE INDICATOR
- FLOW INDICATOR / TOTALIZER

REV. NO.	DR.	CHD.	APPR.	DATE

Rubel and Hager, Inc.
CONSULTING ENGINEERS .... TUCSON, ARIZONA

PROJECT: ROCKY MOUNTAIN ARSENAL, COLORADO

DR. DODD	FLUORIDE REMOVAL PILOT PLANT
CHD. FR	SCHEMATIC FLOW DIAGRAM
APPR. FR	
DATE 3-9-79	DRAWING NUMBER: S-P-100
SCALE NONE	REV.

apparatus, initial start-up procedures began. This entailed placing the treatment media in the vessels and properly back-flushing. Concurrently all instruments were calibrated and mechanical equipment checked out. The EPA Technical Report, "Removal of Excess Fluoride from Drinking Water" by Rubel and Woosley[2] elaborates upon start-up and operating procedures which apply to this type of treatment plant.

During all treatment runs, operating personnel conducted pilot plant surveillance and operating functions which included the following:

1. Monitor raw water flow rate, maintain at 5 gpm ± 1/4 gpm (unless directed otherwise)

2. Monitor raw water pH, maintain at 5.3-5.5 (unless directed otherwise)

3. Sample raw and treated water for analysis at six hour intervals. Record pH and fluoride levels at time of sampling. Collect samples for laboratory analysis.

4. Maintain record at pilot plant of flow rate, total flow, pH and fluoride levels.

5. Maintain supply of dilute acid in solution tank. Record all concentrated acid additions.

Treatment runs were continuous until terminated upon saturation of the treatment bed. Saturation was defined as the point at which the average fluoride level in the treated water exceeded 1.20 mg/l (optimum level for this climate.) In any operational fluoride removal plant equipped with two or more treatment units and/or treated water storage facilities, blending is achieved resulting in constant distribution of optimum levels of fluoride.

The Regeneration Mode included backwash at 7-1/2 gpm for ten to twenty minutes. The bed was then drainned, followed by an upflow regeneration with 100 gallons of 1% sodium hydroxide using softened raw water to dilute 50% sodium hydroxide at a flow rate of 2.5 gpm for forty minutes. This was followed by an upflow soft water rinse of 5 gpm for 120 minutes followed by another draining of the liquid level down to the top of the bed. Finally, a downflow regeneration identical to the upflow described above was accomplished. This was followed by downflow neutralization using soft raw water adjusted to pH 2.5 for 120 minutes. At this point raw water was switched over to unsoftened for the duration of the neutralization and treatment run. When the pH of the treated effluent dropped to 7.5, the pH of the raw water was adjusted to 3.5. When the pH of the treated effluent reached 6.5, the pH of the raw water was adjusted to 5.5 where it remained for the duration of the run.

Wastewater from the regeneration and neutralization was collected in 50 gallon batches for study of ultimate disposal methods. The regeneration described above was not modified during the six test runs.

TEST RESULTS

The fluoride level in the carbon treatment effluent, designated as raw water, remained in the range of 3.6-4.0 mg/l throughout the duration of the pilot plant test program.

Initial tests indicated loss of efficiency due to interference from competing ions in the raw water. However, the interfering ions were regenerated from the bed; and process efficiency experienced no degradation. The bed capacity was directly affected by the quantity of interfering ions present in the raw water. Increased fluoride removal capacity was experienced during treatment runs with lower levels of competing ions. The interfering ions were recovered in the regeneration wastewater and were identified as organics designated as Total Organic Carbon (T.O.C.).

The first five (5) treatment runs employed the planned fluoride removal treatment and regeneration processes. A plot of the data for a typical treatment run (No. 4) is illustrated in Table No. 1; a plot of the test data for a typical regeneration (No. 4) is illustrated in Table No. 2. The only exceptions took place in treatment run number 5 when the flow rate was lowered from 5 gpm to 4 gpm. The change of flow rate had no effect upon the process.

The treatment process was altered during the sixth treatment run to illustrate the raw water pH adjustment effect upon the fluoride removal process. During this run pH adjustment was eleiminated. The treatment bed was neutralized according to the normal process to the raw water pH of 7.3 where it remained during the duration of the run. The result was a loss of two thirds of the fluoride removal capacity during this run. Figures No.2 and No.3 illustrated the comparative performance of treatment runs with and without pH adjustment.

Summary of the results of the test runs are as follows:

Run No.	pH Adjustment	Flow (gpm)	Fluoride Removal grains/ft^3	TOC Removal grains/ft^3
1	yes	5	1350	375
2	yes	5	1550	225
3	yes	5	1650	225
4	yes	5	1750	200
5	yes	4	1700	250
6	no	5	575	not measured

TABLE NO.1

TABULATED DATA TREATMENT RUN NO. 4

				RAW WATER		TREATED WATER		
DATE	TIME	METER READING	TOTAL FLOW	pH	F (mg/l	pH	F mg/l	FLUORIDE TOTAL GRAINS
7/16/79	1730	43820	-	2.5	3.8	11.6	3.4	-
	1830	44120	300	2.5	3.8	9.4	0.65	13
	2000	44560	740	3.5	3.8	6.9	0.10	95
	2400	45730	1910	5.3	3.8	5.4	0.08	348
7/17/79	0600	47480	3660	5.3	3.8	5.4	0.08	727
	1200	49270	5450	5.4	3.8	5.4	0.08	1114
	1800	51030	7210	5.3	3.8	5.3	0.07	1495
	2400	52790	8970	5.3	3.8	5.3	0.08	1876
7/18/79	0600	54540	10720	5.4	3.8	5.3	0.11	2255
	1200	56280	12460	5.5	3.8	5.5	0.15	2631
	1800	57990	14170	5.4	3.8	5.5	0.3	2988
	2400	59700	15880	5.0	3.8	5.0	0.5	3326
7/19/79	0600	61370	17550	5.0	3.8	5.0	0.7	3636
	1200	63210	19390	5.2	3.8	5.5	1.1	3948
	1800	65020	21200	5.6	3.8	5.6	1.4	4214
	2400	66740	22920	5.0	3.8	5.0	1.5	4450
7/20/79	0600	68540	24720	5.0	3.8	5.0	1.5	4692
	1200	70110	26290	5.4	3.8	5.4	1.6	4899
	1800	71880	28060	5.6	3.8	5.4	1.7	5121
	2400	73600	29780	5.2	3.8	5.2	1.8	5327
7/21/79	0600	75450	31630	5.1	3.8	5.1	1.8	5543
	1200	77120	33300	5.4	3.8	5.5	1.9	5733
	1800	78740	34920	5.4	3.8	5.5	2.1	5904
	2400	70420	36600	5.4	3.8	5.4	2.1	6080
7/22/79	0600	82190	38370	5.1	3.8	5.2	2.2	6246
	1200	83920	40100	5.6	3.8	5.6	2.3	6402
	1600	85120	43100	5.4	3.8	5.5	2.3	6507

Total Grains per cubic foot - 1736

TABLE NO. 2

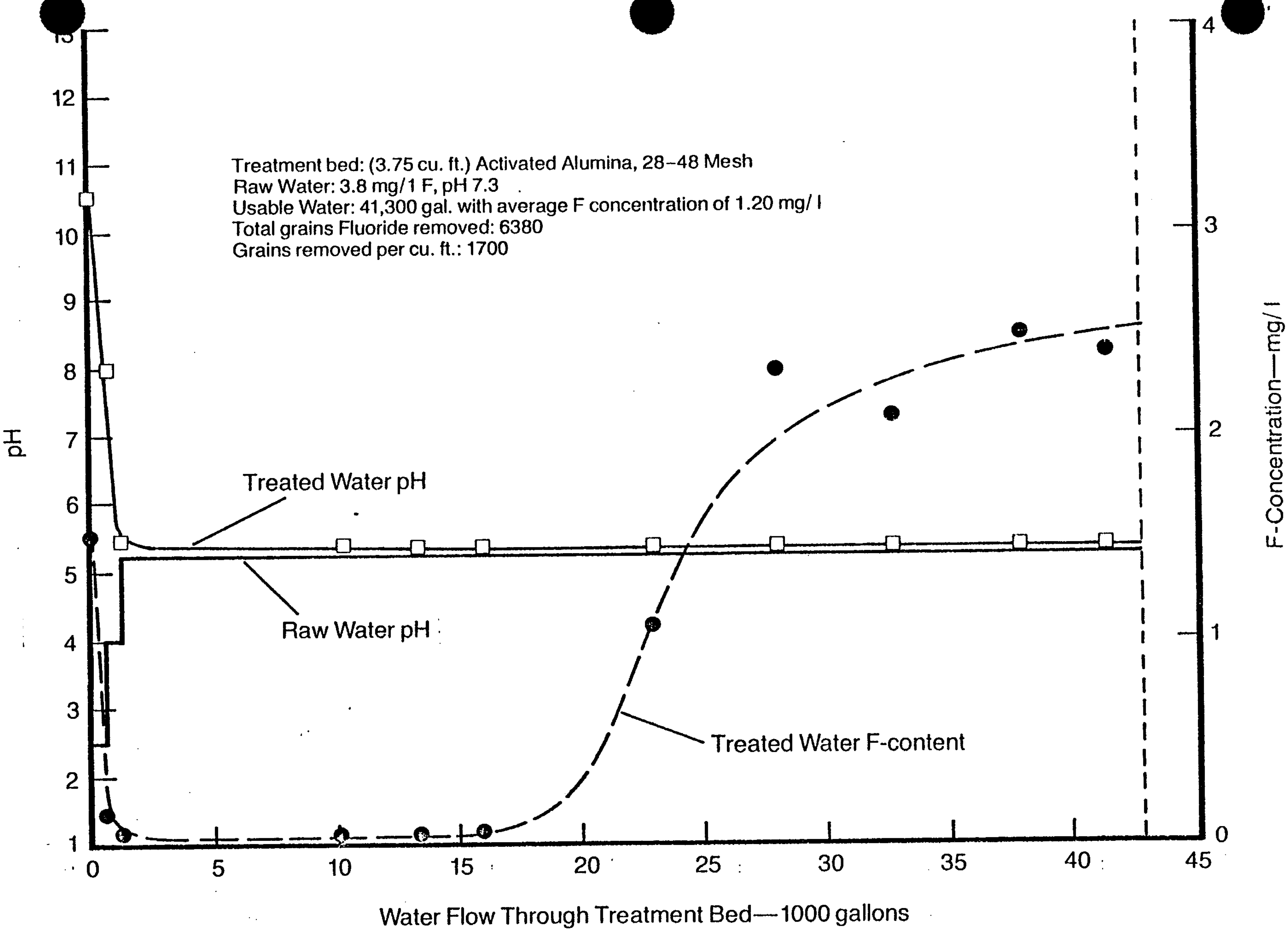
TABULATED DATA - REGENERATION NO. 4

50 GALLON BATCH NO.	pH	F (mg/l)	FLUORIDE TOTAL GRAINS	T.O.C. (mg/l)	T.O.C. TOTAL GRAINS
1	9.7	119	348	55	160
2	12.5	617	2152	21	221
3	12.6	541	3734	76	444
4	12.2	263	4503	88	701
5	11.9	114	4836	11	733
6	11.6	57	5004	5.5	750
7	11.4	32	5097	-	-
8	11.2	27	5176	-	-
9	11.0	21	5237	-	-
10	10.9	17	5287	-	-
11	10.7	16	5333	-	-
12	10.3	13	5371	-	-
13	11.1	102	5669	-	-
14	13.1	239	6367	-	-
15	12.4	59	6539	-	-
16	12.1	21	6601	-	-

Total Grains Fluoride per cubic foot Activated Alumina - 1760

Total Grains T.O.C. per cubic foot Activated Alumina - 200

2.92
119 | 348
238
1100
1071
290
238
520



TYPICAL FLUORIDE REMOVAL PILOT PLANT RUN WITH pH ADJUSTMENT

Figure No. 2

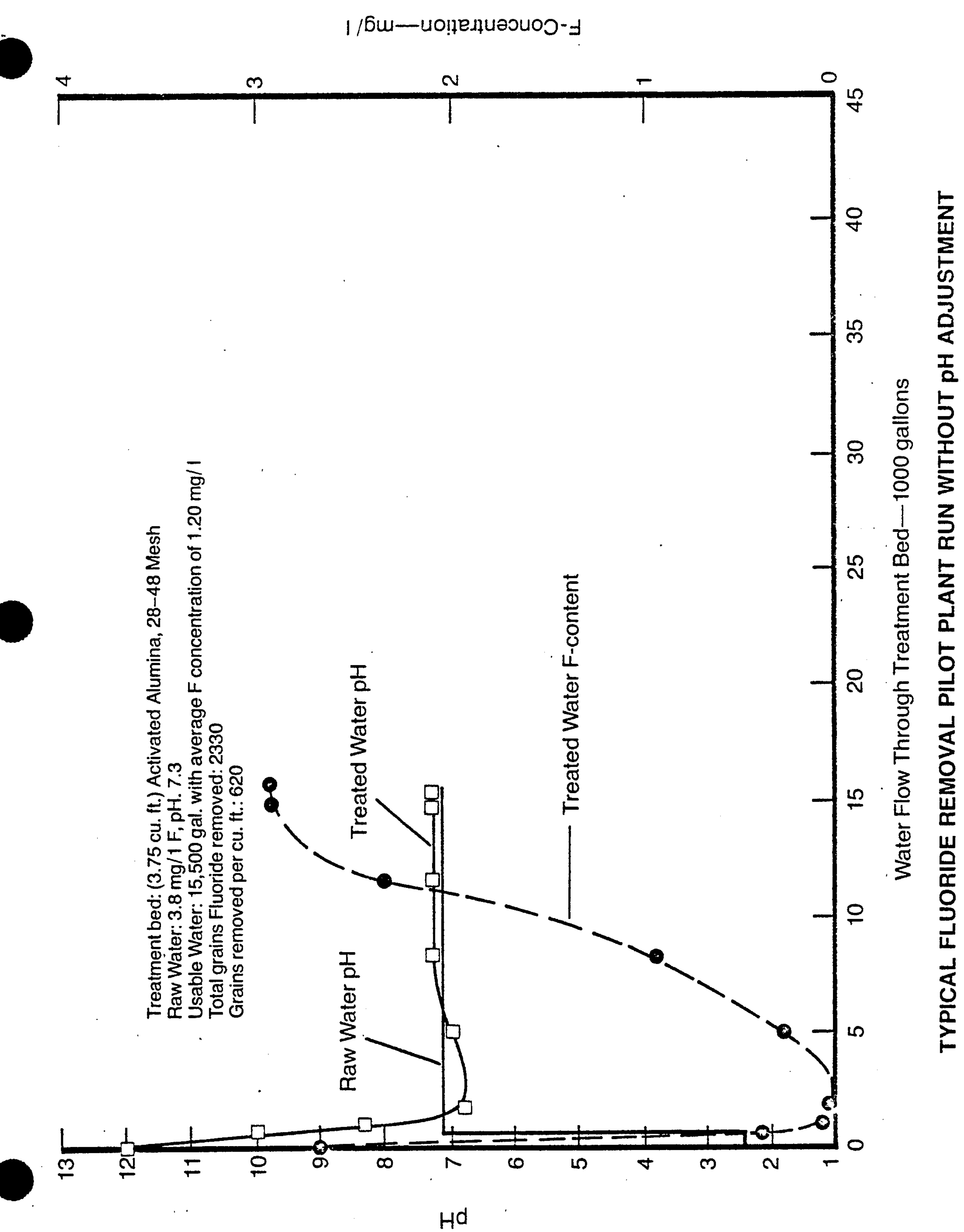

TYPICAL FLUORIDE REMOVAL PILOT PLANT RUN WITHOUT pH ADJUSTMENT
Treatment bed: (3.75 cu. ft.) Activated Alumina, 28–48 Mesh
Raw Water: 3.8 mg/1 F, pH. 7.3
Usable Water: 15,500 gal. with average F concentration of 1.20 mg/l
Total grains Fluoride removed: 2330
Grains removed per cu. ft.: 620
Raw Water pH
Treated Water pH
Treated Water F-content
Water Flow Through Treatment Bed—1000 gallons
pH
F-Concentration—mg/l
0
5
10
15
20
25
30
35
40
45
1
2
3
4
5
6
7
8
9
10
11
12
13
0
1
2
3
4

Figure No. 3

ECONOMICS

During the pilot plant treatment runs and regenerations exact figures on chemical consumption were maintained. Figure 4 illustrates chemical consumption and related chemical costs for pilot plant runs 3, 4, 5 and 6. Chemical costs are current and include delivery to the Arsenal. One can see from this data that when raw water pH adjustment is not employed, chemical costs and wastewater volumes requiring treatment and/or handling will double.

From the pilot test data the operating cost for the full scale fluoride removal water treatment plant have been projected. This cost is approximately 15¢/1000 gallons; see Figure 5.

In the following section design criteria is established for the full scale fluoride removal water treatment plant process equipment. The estimated cost for the installed system is $270,000, see Figure 6.

DESIGN CRITERIA

The design of the Fluoride Removal Water Treatment Plant for the Activated Carbon Effluent (raw water) at the North Boundary of the Rocky Mountain Arsenal, Commerce City, Colorado employing the activated alumina treatment process with caustic regeneration and acid neutralization is to be based on the following criteria:

A. Fluoride levels

1. Raw Water - 3.5-4.0 mg/l

2. Treated Water - 1.2 mg/l (avg.)

B. Treatment

1. Material Spec. - Alcoa Activated Alumina - Grade F-1, -28 + 48 mesh

2. Bed Design

- Number of beds (treatment units) - 2

- Bed depth - 5'-0"

- Bed expansion during backwash - 50% = 2'-6"

- Tank free board - 6"

- Superficial residence time of raw water flowing through bed - 5 minutes (min)

- Treatment unit flow rate - 7 gpm/ft.^{2} (max)

Pilot Plant Treatment Chemical Cost and Wastewater Summary

* *With acid neutralization but without pH adjustment during run*

Pilot Plant Run N
Total Treated W
Acid Consumed
Acid Consumed
Gallons of Acid (
1000 gal. trea
Cost of Acid/
1000 gal. trea
@ 44½¢/gal. (

Caustic Consum
Gallons of Caus
1000 gal. trea
Cost of Caustic/
1000 gal. trea
@ 88¢/gal. of

Softener Salt Co
Lb. of Softener S
1000 gal. treat
Cost of Softener
1000 gal. treat
@ 2.9¢/lb. of s

Total Chemical C
1000 gal. of tre

Recycle (backwa
neutralization
% Treated Wa

High Fluoride
Waste Water
% Treated Wa

'lant Run Number	3	4	5	*6
Treated Water Flow/gallons	42,600	41,300	41,300	15,500
;onsumed (ml)	27,300	23,800	21,600	7,000
;onsumed gallons	7.21	6.29	5.71	1.85
ns of Acid Consumed/)0 gal. treated water	0.17	0.15	0.14	.12
of Acid/)0 gal. treated water, 14½¢/gal. of acid	.075¢	.068¢	.061¢	.053¢
ic Consumed gallons	2.67	2.67	2:67	2.67
ns of Caustic Consumed/)0 gal. treated water	.063	.065	.065	.172
of Caustic/)0 gal. treated water, 38¢/gal. of caustic	.055¢	.057¢	.057¢	.152¢
ner Salt Consumed/lbs.	25	25	25	25
Softener Salt Consumed/ 0 gal. treated water	.587	.605	.605	1.61
of Softener Salt/ 0 gal. treated water, 2.9¢/lb. of softener salt	.017¢	.018¢	.018¢	.047¢
;hemical Cost/ 0 gal. of treated water	14.7¢	14.3¢	13.6¢	25.2¢
le (backwash + tralization water-gallons)	300	500	400	200
reated Water	1%	1%	1%	1%
luoride ste Water	1000	900	700	600
reated Water	2½%	2%	1¾%	4%

Rocky Mountain Arsenal Fluoride Removal Water Treatment Plant

Operating Cost Projection

		Cost per 1000 gallons treated water
1. Chemicals		
a. 66° Baume H_2SO_4 at 44.5¢/gallon		$.061
b. 50% NaOH at 88¢/gallon		.057
c. Salt at 2.9¢/lb.		.018
	Subtotal	$.136
2. Operator (existing)		
3. Alumina Replacement 3% per year @ 40¢/lb.		$.002
4. Miscellaneous supplies and services		.007
5. Electric Utility @ 5¢/kwh		.012
	Total	$.157

Figure No. 5

Rocky Mountain Arsenal Fluoride Removal Water Treatment Plant Capital Cost Estimate

Process Equipr
Treatment Vessels
Process Piping an
Treatment Media
Chemical Storage
Chemical Pumps,
Regeneration Soft

Process Equipr
Mechanical
Electrical
Miscellaneous

Miscellaneous I
Slabs, Foundation
Pre-Engineered St

Miscellaneous
Freight & Taxes
Contingencies

Fees
Engineering
Other

ss Equipment		
ient Vessels		$ 28,000
ss Piping and Installation		24,000
ient Media		17,000
cal Storage Vessels		14,000
cal Pumps, Piping and Accessories		7,000
eration Softener		20,000
	Subtotal	$110,000
ss Equipment Installation		
nical		$ 20,000
cal		15,000
laneous		15,000
	Subtotal	$ 50,000
llaneous Installed Items		
Foundations, Earthwork, Site Work		$ 25,000
igineered Steel Building		25,000
	Subtotal	$ 50,000
llaneous		
t & Taxes		$ 8,000
gencies		17,000
	Subtotal	$ 25,000
ering		$ 25,000
		10,000
	Subtotal	$ 35,000
	Total	$270,000

Figure No. 6

- Treatment unit backwash flow rate - 10 gpm/ft.^{2} (max)

3. Treatment Unit Design

   - 50 psi ASME unfired pressure vessel code design
   - Rubber lined
   - Access manway at top with platform, drain at bottom
   - Lifting lugs
   - Skid mounted
   - Air bleed vent/vacuum break
   - Internal header and lateral collection pipe system
   - Distribution baffle
   - Inlet and outlet flanges

4. Piping System Design

   - Liquid velocities (except backwash) - 10 ft./sec. (max)
   - Liquid velocity - backwash - 13 ft./sec. (max)
   - Material suitable for dilute acid and dilute caustic service
   - Manual valves - butterfly, gate
   - Measure flow rate into unit, total flow into unit
   - Sampling system to monitor pH and Fluoride
   - Control treatment system flow rate
   - Control treatment system pressure

C. <u>Quantity and Quality of Treated Water for Distribution</u>

1. Raw water flow rate- 1000 gpm (max). Treatment unit design. Flow rate 300 gpm each, or 600 gpm.

2. Treated water total flow - 97% raw water flow - 840,000 GPD.

3. Waste water - 3% raw water flow - 26,000 GPD.

4. Measure fluoride content of treated water.

5. Measure pH level of treated water. Include high and low pH alarms interlocked with raw water pump power supply; thereby plant will sound alarm and will shut down in the event of high or low pH. Include provision to flush system to waste in the event of high or low pH shut down. Manual start-up only after shutdown.

6. Incorporate provisions to lower raw water pH and raise treated water pH.

D. <u>Regeneration and Neutralization</u>

1. Regeneration material - 1% NaOH

   - Blend of 50% NaOH and softened raw water in "mixing T" at treatment unit

   - 50% NaOH procured directly from caustic manufacturer, delivered to plant in tank trucks

   - Provide 6000 gallon insulated caustic storage tank (horizontal) with manway, immersion heater (incl. controls) to maintain 70° F min., lifting lugs, vent w/overflow, fill piping, drain piping, level measurement capability and outlets to service.

2. Regeneration process

   - Flow rate through treatment unit - 2-1/2 gpm/ft.^{2} (max)

   - Residence time in treatment bed - 40 minutes (min)

   - Incorporate provision for upflow or downflow through bed

3. Regeneration Equipment

   - Chemical pump - Metering pumps with precision flow control. Corrosion resistant material - Interlock pump controls with well pump power supply so that chemical pump can't operate when pump is off. Pump mounted upon steel stand above Day Tank. Day Tank filled via gravity from Caustic Storage

   - Plug valves, check valves, pressure relief valves and back-pressure valves as required for total operational control and good maintenance.

   - Provide emergency shower and eyewash

4. Neutralization material - 0.04% H_2SO_4

- Blend of 93% H_2SO_4 and softened water in "mixing T" at treatment unit

- 93% H_2SO_4 procured directly from acid manufacturer, delivered to plant in tank trucks

- Provide 6000 gallon acid storage horizonizontal tank with manway, lifting lugs, vent w/overflow, fill piping, drain piping, level measurement capability and outlet to service

5. Neutralization process

   - Flow rate through treatment unit - 7 gpm/ft.^{2} (max)

   - Amount of acid rinse required - sufficient to adjust pH within acceptable pH limits 6.5 - 8.5

   - Incorporate provision for upflow or downflow through bed

6. Neutralization equipment

   - Chemical pumps - 2 Metering pumps with precision flow control. Corrosion resistant material. Interlock pump controls with well pump supply so that chemical pumps cannot operate when well pump is off. Pumps mounted upon steel stand above Day Tank. Day Tank filled via gravity from Acid Storage Tank.

   - Plug valves, check valves, pressure relief valves and back-pressure valves as required for total operational control and good maintenance.

7. - Zeolite softener complete with brine tank and automatic regeneration. Size softener to remove hardness ions from 300 gallons (min.) of raw water per cubic feet of activated alumina in individual treatment unit. Hardness level during pilot testing was 30 grains per gallon. Include manual isolation valves to employ softened water only during regeneration.

E. Treatment Building

1. Provide facility to house Treatment Units, Chemical Handling Systems, and Sampling System.

2. House operator's tools, supplies, records, etc.

3. House chemical test equipment with lab sink, counter and cabinets.

. Abide by Applicable Portions of the Following Codes and Standards

1. ASME Boiler & Pressure Vessel Code - Section VIII, Division 1
2. ASTM
3. AWWA
4. American Concrete Institute Building Code - 318
5. National Electric Code
6. National Sanitation Foundation Standards
7. Manufacturing Chemists Association
    a. Chemical Safety Data Sheet SD-9 Caustic Soda
    b. Chemical Safety Data Sheet SD-20 Sulfuric Acid
8. OSHA
9. Uniform Building Code

CONCLUSIONS

The fluoride removal pilot test runs have demonstrated that a full scale fluoride removal water treatment plant with raw water pH adjustment, can reliably remove 1700 grains of fluoride per cubic foot of activated alumina. Operating treatment cost projection for the full scale plant is 15¢/1000 gallons. Capital cost estimate for the 1000 gpm treatment system is $270,000.

Interfering ions present in the raw water are competing fluoride for adsorption sites on the granular activated alumina surfaces. The interfering ions have been identified as T.O.C. Although the T.O.C. is easily removed during regeneration, its presence does reduce the fluoride removal capacity of the activated alumina to the above mentioned 1700 grains per cubic foot.

The use of softened raw water during regeneration and neutralization has increased the efficiency of the regeneration process.

BIBLIOGRAPHY

1. Rubel and Hager, Inc., "Feasibility Study for the Removal of Excess Fluoride from Activated Carbon Effluent", The Deaprtment of the Army, Rocky Mountain Arsenal (Ref. #DAAA05-78-M-0914), ITARMS Project No. 1.05.15, September 30, 1978

2. Rubel, Jr., Frederick and Woosley, R. Dale, "Removal of Excess Fluoride from Drinking Water", Technical Report EPA 570/9-78-001, Jan. 1978

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FINAL REPC...

ON

PILOT TEST PROGRAM

FOR

REMOVAL OF EXCESS FLUORIDE

FROM

ACTIVATED CARBON EFFLUENT

FOR

THE DEPARTMENT OF THE ARMY
ROCKY MOUNTAIN ARSENAL
(REF. CONTRACT #DAAA05-79-C-006)

By

Rubel and Hager, Inc.
4400 E. Broadway, Suite 710
Tucson, Arizona 85711

November 30, 1979

Copies

1 - 6: Carl G. Loven

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INTRODUCTION

In accordance with a directive from the Colorado Department of Health, the reinjection water at the north boundary of the Rocky Mountain Arsenal will be subject to drinking water standards established by the U. S. Environmental Protection Agency and the Colorado Department of Health. In addition to organic limitations for which purpose the granular activated carbon system was installed, there is also a specific limit of 2.4 mg/l of fluoride.

In response to this directive, this firm, Rubel and Hager, Inc. was engaged by the Rocky Mountain Arsenal to perform a feasibility study[1] during September 1978. The results of that study documented that using the activated alumina treatment method the excess fluoride can be removed from the carbon treated water at the reinjection site. That study, consisting of two complete treatment cycles including chemical regeneration, demonstrated the removal of fluoride from levels of 4-5 mg/l to an average of 1 mg/l. A capacity of more than 2,000 grains of fluoride per cubic foot of activated alumina was achieved in both cycles. That fluoride removal level is far below the maximum contaminant level requirement for fluoride of 2.4 mg/l established by the EPA and the Colorado Department of Health. At the conclusion of the feasibility study, it was determined that further pilot testing would be necessary to optimize the caustic regeneration procedure for maximum long term economy. Therefore, this pilot test program was established.

The purpose of this program was to determine whether there are any interferences present in the activated carbon effluent that may reduce the efficiency of the process. An optimum alumina regeneration process will be developed to minimize operating costs. The working capacity of the activated alumina along with chemical consumption upon which a full-scale plant can be designed will be determined.

TEST APPARATUS

The test apparatus is a fully assembled skid-mounted treatment system (see Figure 1 for Schematic Flow Diagram). The system is designed to treat the activated carbon effluent at the rate of 5 gpm at 50 psig maximum working pressure. There are two treatment vessels (fourteen-inch diameter by ninety six inches high) each contains 3.75 cubic feet of Alcoa (grade F-1, - 28+48 mesh) activated alumina. This manually operated system is piped to permit one treatment unit to perform design flow treatment individually, or two units can be operated in either series or parallel. The system contains 1" PVC schedule 80 threaded pipe and fittings with manually operated full port ball valves. Accessories for each treatment unit include pH sensors with panel mounted indicators at inlet and outlet, sample points at inlet and outlet, a pressure gauge, an air vent, a flow totalizer, injection points for acid and caustic, and an in-line static chemical mixer.

The system also includes a feed water pump, a caustic feed system, an acid feed system, a zeolite softener, and sample points. The caustic feed system includes one twelve gallon solution tank and one metering pump for 50% sodium hydroxide. The caustic is employed during regeneration only; therefore, one pump serves both treatment units. The acid feed system includes one fifty gallon solution tank and two metering pumps for dilute sulfuric acid. One acid pump is required for pH adjustment for each treatment unit. The zeolite softener is an optional feature which can be used to pretreat raw water during caustic regeneration. There are also provisions for adding other pretreatment equipment, or additional treatment units.

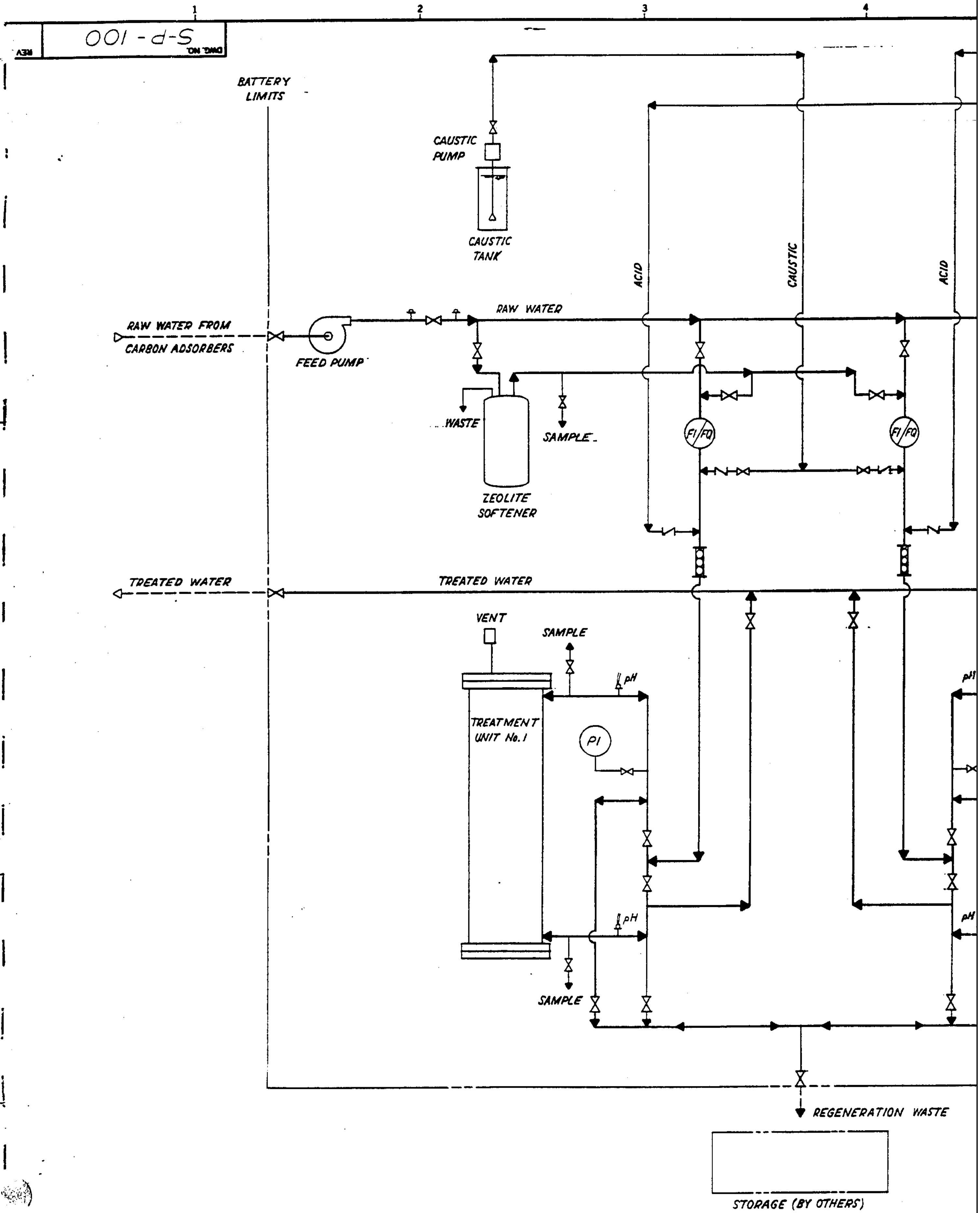
The entire treatment system is mounted on a steel skid (six feet wide by ten feet long) which is elevated approximately eighteen inches above the floor. The skid is located adjacent to the activated carbon system in the north boundary treatment building. Raw water is piped from the carbon adsorbers to the feed water pump suction. The treated water is piped to a designated discharge point. Regeneration wastewater is collected in 50 gallon drums for analysis and waste treatment process development.

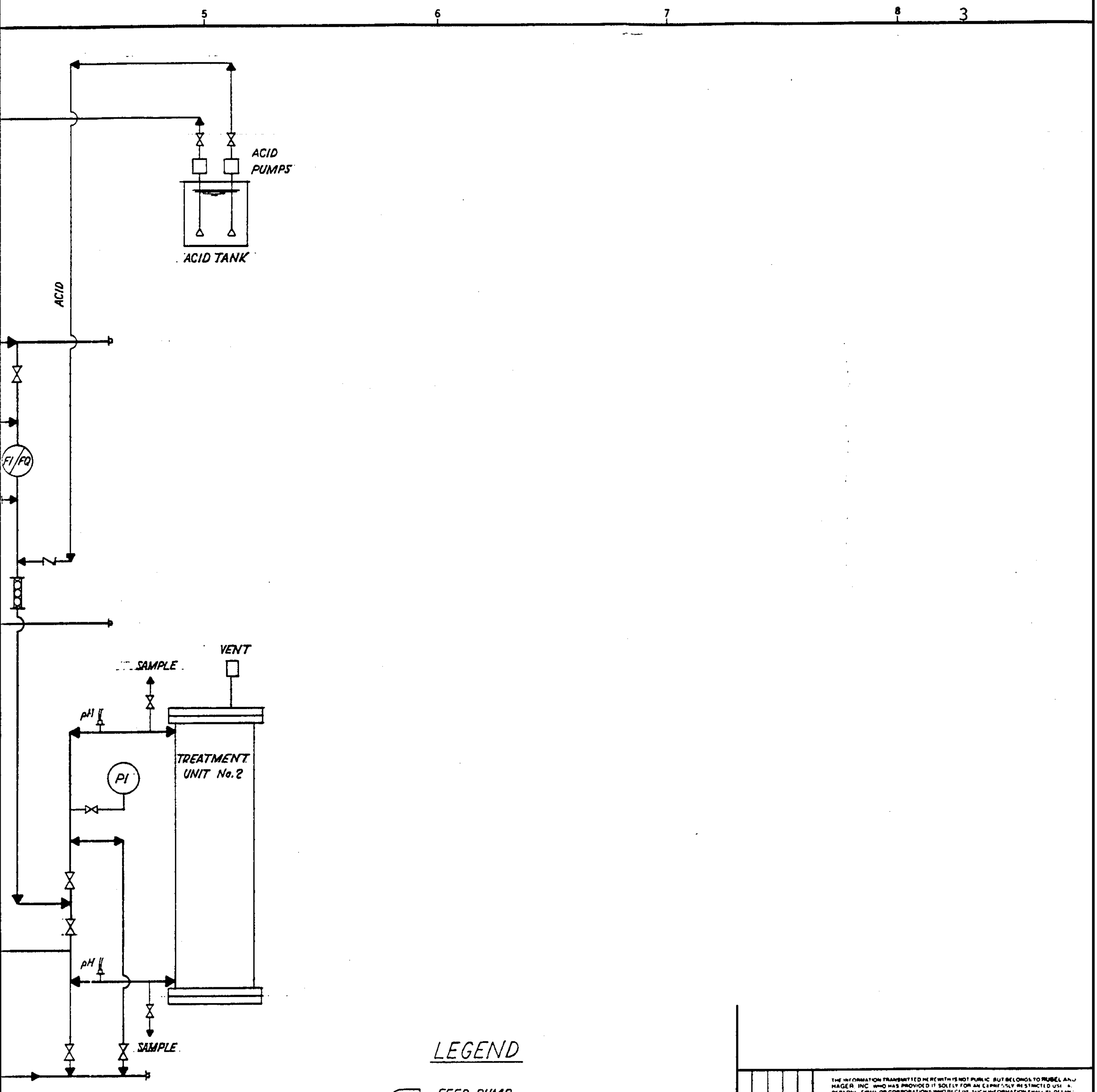
TEST PROGRAM

The scope of the test program for the 5 gpm pilot included six complete treatment cycles. Each cycle consisted of a treatment run through exhaustion of the treatment bed followed by a chemical regeneration.

Treatment Unit No. 1 was designated as the primary treatment unit; Treatment Unit No. 2 was designated as the standby treatment unit. All testing took place in the primary unit.

Upon completion of the installation of the pilot plant test


1
2
3
4
REV.
DWG. NO.
S-P-100
BATTERY LIMITS
CAUSTIC PUMP
CAUSTIC TANK
ACID
CAUSTIC
ACID
RAW WATER
RAW WATER FROM CARBON ADSORBERS
FEED PUMP
WASTE
SAMPLE
ZEOLITE SOFTENER
FI/FQ
FI/FQ
TREATED WATER
TREATED WATER
VENT
SAMPLE
pH
TREATMENT UNIT No. 1
PI
pH
pH
pH
SAMPLE
REGENERATION WASTE
STORAGE (BY OTHERS)



LEGEND

- FEED PUMP
- IN LINE STATIC MIXER
- INJECTION BALL CHECK
- SHUT OFF VALVE
- PI — PRESSURE INDICATOR
- FI/FQ — FLOW INDICATOR/TOTALIZER

REV. NO.	DR.	CHD.	APPR.	DATE

Rubel and Hager, Inc.
CONSULTING ENGINEERS .... TUCSON, ARIZONA

0 1 2

PROJECT: ROCKY MOUNTAIN ARSENAL, COLORADO

DR. DODD	FLUORIDE REMOVAL PILOT PLANT
CHD. FR	SCHEMATIC FLOW DIAGRAM
APPR. FR	
DATE 3-9-79	**DRAWING NUMBER** S-P-100
SCALE NONE	**REV.**

apparatus, initial start-up procedures began. This entailed placing the treatment media in the vessels and properly back-flushing. Concurrently all instruments were calibrated and mechanical equipment checked out. The EPA Technical Report, "Removal of Excess Fluoride from Drinking Water" by Rubel and Woosley[2] elaborates upon start-up and operating procedures which apply to this type of treatment plant.

During all treatment runs, operating personnel conducted pilot plant surveillance and operating functions which included the following:

1. Monitor raw water flow rate, maintain at 5 gpm ± 1/4 gpm (unless directed otherwise)

2. Monitor raw water pH, maintain at 5.3-5.5 (unless directed otherwise)

3. Sample raw and treated water for analysis at six hour intervals. Record pH and fluoride levels at time of sampling. Collect samples for laboratory analysis.

4. Maintain record at pilot plant of flow rate, total flow, pH and fluoride levels.

5. Maintain supply of dilute acid in solution tank. Record all concentrated acid additions.

Treatment runs were continuous until terminated upon saturation of the treatment bed. Saturation was defined as the point at which the average fluoride level in the treated water exceeded 1.20 mg/l (optimum level for this climate.) In any operational fluoride removal plant equipped with two or more treatment units and/or treated water storage facilities, blending is achieved resulting in constant distribution of optimum levels of fluoride.

The Regeneration Mode included backwash at 7-1/2 gpm for ten to twenty minutes. The bed was then drainned, followed by an upflow regeneration with 100 gallons of 1% sodium hydroxide using softened raw water to dilute 50% sodium hydroxide at a flow rate of 2.5 gpm for forty minutes. This was followed by an upflow soft water rinse of 5 gpm for 120 minutes followed by another draining of the liquid level down to the top of the bed. Finally, a downflow regeneration identical to the upflow described above was accomplished. This was followed by downflow neutralization using soft raw water adjusted to pH 2.5 for 120 minutes. At this point raw water was switched over to unsoftened for the duration of the neutralization and treatment run. When the pH of the treated effluent dropped to 7.5, the pH of the raw water was adjusted to 3.5. When the pH of the treated effluent reached 6.5, the pH of the raw water was adjusted to 5.5 where it remained for the duration of the run.

Wastewater from the regeneration and neutralization was collected in 50 gallon batches for study of ultimate disposal methods. The regeneration described above was not modified during the six test runs.

TEST RESULTS

The fluoride level in the carbon treatment effluent, designated as raw water, remained in the range of 3.6-4.0 mg/l throughout the duration of the pilot plant test program.

Initial tests indicated loss of efficiency due to interference from competing ions in the raw water. However, the interfering ions were regenerated from the bed; and process efficiency experienced no degradation. The bed capacity was directly affected by the quantity of interfering ions present in the raw water. Increased fluoride removal capacity was experienced during treatment runs with lower levels of competing ions. The interfering ions were recovered in the regeneration wastewater and were identified as organics designated as Total Organic Carbon (T.O.C.).

The first five (5) treatment runs employed the planned fluoride removal treatment and regeneration processes. A plot of the data for a typical treatment run (No. 4) is illustrated in Table No. 1; a plot of the test data for a typical regeneration (No. 4) is illustrated in Table No. 2. The only exceptions took place in treatment run number 5 when the flow rate was lowered from 5 gpm to 4 gpm. The change of flow rate had no effect upon the process.

The treatment process was altered during the sixth treatment run to illustrate the raw water pH adjustment effect upon the fluoride removal process. During this run pH adjustment was eleiminated. The treatment bed was neutralized according to the normal process to the raw water pH of 7.3 where it remained during the duration of the run. The result was a loss of two thirds of the fluoride removal capacity during this run. Figures No.2 and No.3 illustrated the comparative performance of treatment runs with and without pH adjustment.

Summary of the results of the test runs are as follows:

Run No.	pH Adjustment	Flow (gpm)	Fluoride Removal grains/ft^3	TOC Removal grains/ft^3
1	yes	5	1350	375
2	yes	5	1550	225
3	yes	5	1650	225
4	yes	5	1750	200
5	yes	4	1700	250
6	no	5	575	not measured

TABLE NO.1

TABULATED DATA TREATMENT RUN NO. 4

DATE	TIME	METER READING	TOTAL FLOW	RAW WATER pH	RAW WATER F(mg/l	TREATED WATER pH	TREATED WATER F mg/l	TREATED WATER FLUORIDE TOTAL GRAINS
7/16/79	1730	43820	-	2.5	3.8	11.6	3.4	-
	1830	44120	300	2.5	3.8	9.4	0.65	13
	2000	44560	740	3.5	3.8	6.9	0.10	95
	2400	45730	1910	5.3	3.8	5.4	0.08	348
7/17/79	0600	47480	3660	5.3	3.8	5.4	0.08	727
	1200	49270	5450	5.4	3.8	5.4	0.08	1114
	1800	51030	7210	5.3	3.8	5.3	0.07	1495
	2400	52790	8970	5.3	3.8	5.3	0.08	1876
7/18/79	0600	54540	10720	5.4	3.8	5.3	0.11	2255
	1200	56280	12460	5.5	3.8	5.5	0.15	2631
	1800	57990	14170	5.4	3.8	5.5	0.3	2988
	2400	59700	15880	5.0	3.8	5.0	0.5	3326
7/19/79	0600	61370	17550	5.0	3.8	5.0	0.7	3636
	1200	63210	19390	5.2	3.8	5.5	1.1	3948
	1800	65020	21200	5.6	3.8	5.6	1.4	4214
	2400	66740	22920	5.0	3.8	5.0	1.5	4450
7/20/79	0600	68540	24720	5.0	3.8	5.0	1.5	4692
	1200	70110	26290	5.4	3.8	5.4	1.6	4899
	1800	71880	28060	5.6	3.8	5.4	1.7	5121
	2400	73600	29780	5.2	3.8	5.2	1.8	5327
7/21/79	0600	75450	31630	5.1	3.8	5.1	1.8	5543
	1200	77120	33300	5.4	3.8	5.5	1.9	5733
	1800	78740	34920	5.4	3.8	5.5	2.1	5904
	2400	70420	36600	5.4	3.8	5.4	2.1	6080
7/22/79	0600	82190	38370	5.1	3.8	5.2	2.2	6246
	1200	83920	40100	5.6	3.8	5.6	2.3	6402
	1600	85120	43100	5.4	3.8	5.5	2.3	6507

Total Grains per cubic foot - 1736

TABLE NO. 2

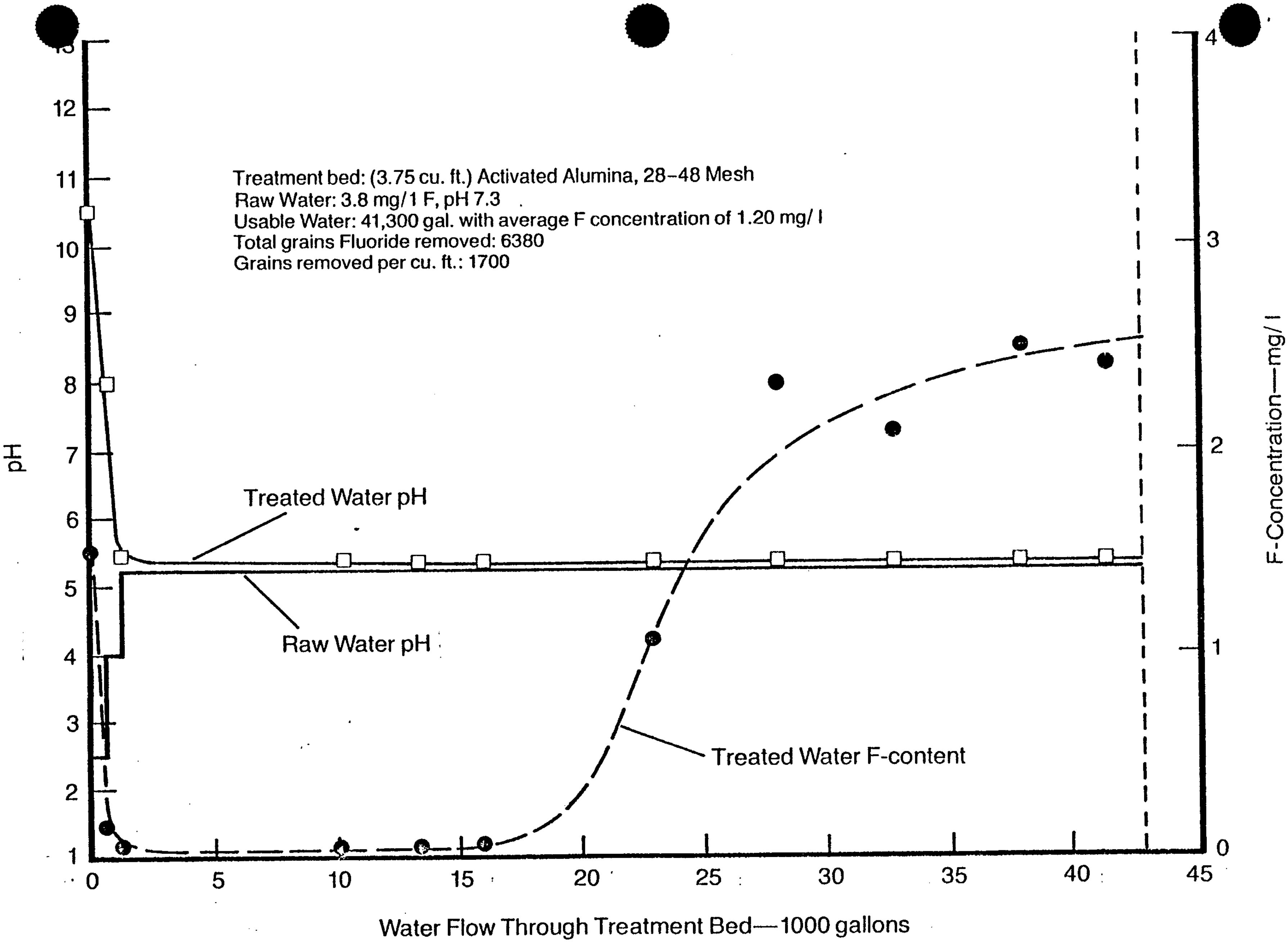
TABULATED DATA - REGENERATION NO. 4

50 GALLON BATCH NO.	pH	F(mg/l)	FLUORIDE TOTAL GRAINS	T.O.C. (mg/l)	T.O.C. TOTAL GRAINS
1	9.7	119	348	55	160
2	12.5	617	2152	21	221
3	12.6	541	3734	76	444
4	12.2	263	4503	88	701
5	11.9	114	4836	11	733
6	11.6	57	5004	5.5	750
7	11.4	32	5097	-	-
8	11.2	27	5176	-	-
9	11.0	21	5237	-	-
10	10.9	17	5287	-	-
11	10.7	16	5333	-	-
12	10.3	13	5371	-	-
13	11.1	102	5669	-	-
14	13.1	239	6367	-	-
15	12.4	59	6539	-	-
16	12.1	21	6601	-	-

Total Grains Fluoride per cubic foot Activated Alumina - 1760

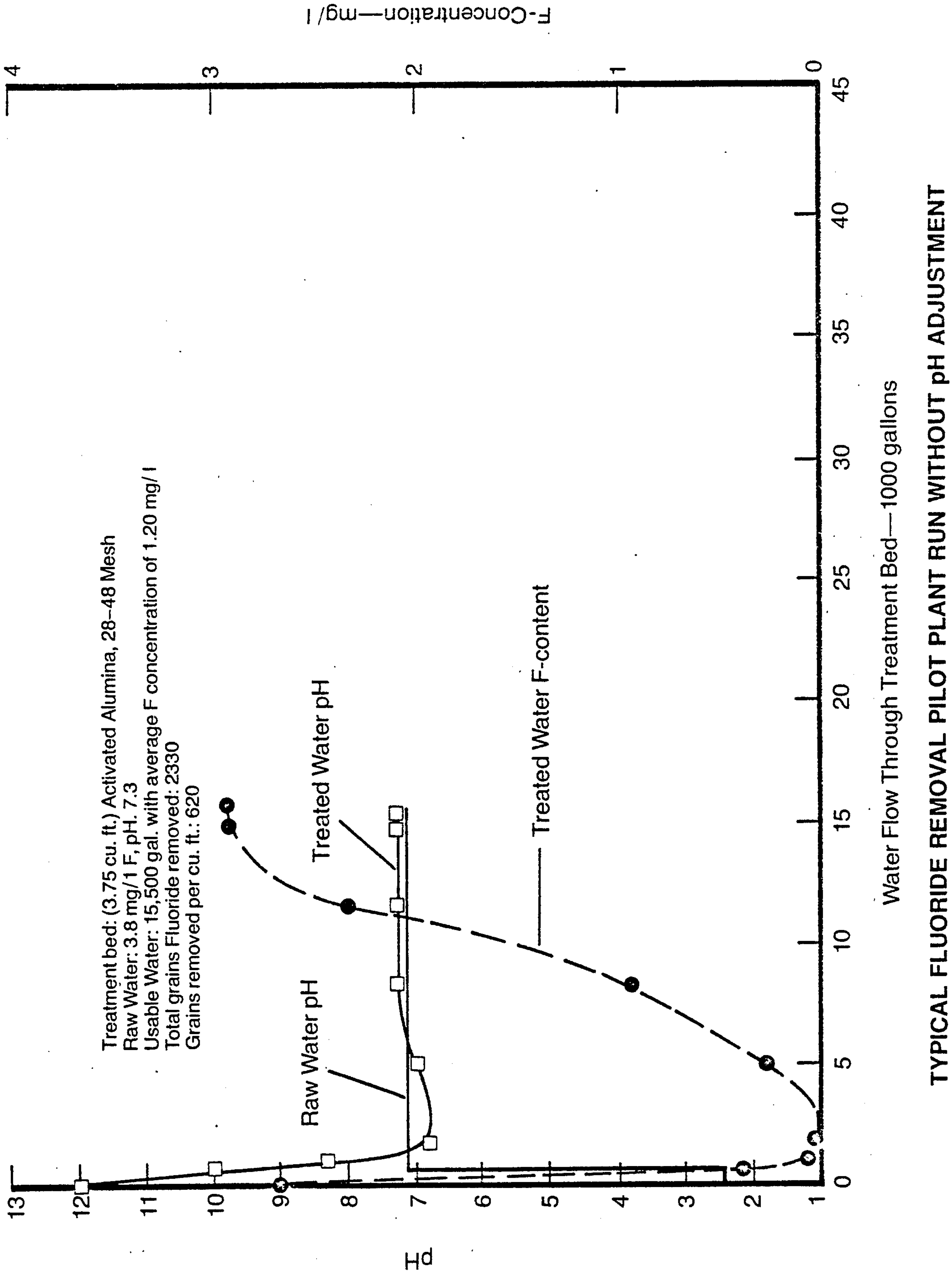
Total Grains T.O.C. per cubic foot Activated Alumina - 200

2.92
119 | 348
238
1100
1071
290
238
520



TYPICAL FLUORIDE REMOVAL PILOT PLANT RUN WITH pH ADJUSTMENT

Figure No. 2



TYPICAL FLUORIDE REMOVAL PILOT PLANT RUN WITHOUT pH ADJUSTMENT
Treatment bed: (3.75 cu. ft.) Activated Alumina, 28–48 Mesh
Raw Water: 3.8 mg/1 F, pH. 7.3
Usable Water: 15,500 gal. with average F concentration of 1.20 mg/l
Total grains Fluoride removed: 2330
Grains removed per cu. ft.: 620
Raw Water pH
Treated Water pH
Treated Water F-content
F-Concentration—mg/ l
pH
Water Flow Through Treatment Bed—1000 gallons

Figure No. 3

ECONOMICS

During the pilot plant treatment runs and regenerations exact figures on chemical consumption were maintained. Figure 4 illustrates chemical consumption and related chemical costs for pilot plant runs 3, 4, 5 and 6. Chemical costs are current and include delivery to the Arsenal. One can see from this data that when raw water pH adjustment is not employed, chemical costs and wastewater volumes requiring treatment and/or handling will double.

From the pilot test data the operating cost for the full scale fluoride removal water treatment plant have been projected. This cost is approximately 15¢/1000 gallons; see Figure 5.

In the following section design criteria is established for the full scale fluoride removal water treatment plant process equipment. The estimated cost for the installed system is $270,000, see Figure 6.

DESIGN CRITERIA

The design of the Fluoride Removal Water Treatment Plant for the Activated Carbon Effluent (raw water) at the North Boundary of the Rocky Mountain Arsenal, Commerce City, Colorado employing the activated alumina treatment process with caustic regeneration and acid neutralization is to be based on the following criteria:

A. Fluoride levels

1. Raw Water - 3.5-4.0 mg/l

2. Treated Water - 1.2 mg/l (avg.)

B. Treatment

1. Material Spec. - Alcoa Activated Alumina - Grade F-1, -28 + 48 mesh

2. Bed Design

- Number of beds (treatment units) - 2
- Bed depth - 5'-0"
- Bed expansion during backwash - 50% = 2'-6"
- Tank free board - 6"
- Superficial residence time of raw water flowing through bed - 5 minutes (min)
- Treatment unit flow rate - 7 gpm/ft.^{2} (max)

Pilot Plant
Treatment Chemical Cost
and
Wastewater Summary

Pilot Plant Run
Total Treated W
Acid Consume
Acid Consume
Gallons of Acid 1000 gal. tre
Cost of Acid/ 1000 gal. trea @ 44½¢/gal.
Caustic Consur
Gallons of Caus 1000 gal. trea
Cost of Caustic 1000 gal. trea @ 88¢/gal. of
Softener Salt C
Lb. of Softener 1000 gal. trea
Cost of Softene 1000 gal. trea @ 2.9¢/lb. of
Total Chemical 1000 gal. of t
Recycle (backw neutralization % Treated W
High Fluoride Waste Water % Treated W

* *With acid neutralization but without pH adjustment during run*

ant Run Number	3	4	5	*6
eated Water Flow/gallons	42,600	41,300	41,300	15,500
nsumed (ml)	27,300	23,800	21,600	7,000
nsumed gallons	7.21	6.29	5.71	1.85
s of Acid Consumed/ gal. treated water	0.17	0.15	0.14	.12
Acid/ gal. treated water, 1½¢/gal. of acid	.075¢	.068¢	.061¢	.053¢
Consumed gallons	2.67	2.67	2:67	2.67
s of Caustic Consumed/ gal. treated water	.063	.065	.065	.172
Caustic/ gal. treated water, 3¢/gal. of caustic	.055¢	.057¢	.057¢	.152¢
er Salt Consumed/lbs.	25	25	25	25
oftener Salt Consumed/ gal. treated water	.587	.605	.605	1.61
Softener Salt/ gal. treated water, 9¢/lb. of softener salt	.017¢	.018¢	.018¢	.047¢
hemical Cost/ gal. of treated water	14.7¢	14.3¢	13.6¢	25.2¢
e (backwash + alization water-gallons)	300	500	400	200
eated Water	1%	1%	1%	1%
uoride e Water	1000	900	700	600
eated Water	2½%	2%	1¾%	4%

Rocky Mountain Arsenal Fluoride Removal Water Treatment Plant Operating Cost Projection

		Cost per 1000 gallons treated water
1. Chemicals		
a. 66° Baume H_2SO_4 at 44.5¢/gallon		$.061
b. 50% NaOH at 88¢/gallon		.057
c. Salt at 2.9¢/lb.		.018
	Subtotal	$.136
2. Operator (existing)		
3. Alumina Replacement		
3% per year @ 40¢/lb.		$.002
4. Miscellaneous supplies and services		.007
5. Electric Utility @ 5¢/kwh		.012
	Total	$.157

Figure No. 5

Rocky Mountain Arsenal
Fluoride Removal
Water Treatment Plant
Capital Cost Estimate

Process Equip
Treatment Vessel
Process Piping ar
Treatment Media
Chemical Storage
Chemical Pumps,
Regeneration Sof

Process Equip
Mechanical
Electrical
Miscellaneous

Miscellaneous
Slabs, Foundatior
Pre-Engineered S

Miscellaneous
Freight & Taxes
Contingencies

Fees
Engineering
Other

ss Equipment		
ent Vessels		$ 28,000
s Piping and Installation		24,000
ent Media		17,000
cal Storage Vessels		14,000
cal Pumps, Piping and Accessories		7,000
eration Softener		20,000
	Subtotal	$110,000
ss Equipment Installation		
nical		$ 20,000
al		15,000
aneous		15,000
	Subtotal	$ 50,000
llaneous Installed Items		
Foundations, Earthwork, Site Work		$ 25,000
gineered Steel Building		25,000
	Subtotal	$ 50,000
llaneous		
& Taxes		$ 8,000
gencies		17,000
	Subtotal	$ 25,000
ering		$ 25,000
		10,000
	Subtotal	$ 35,000
	Total	$270,000

Figure No. 6

- Treatment unit backwash flow rate - 10 $gpm/ft.^2$ (max)

3. Treatment Unit Design

   - 50 psi ASME unfired pressure vessel code design
   - Rubber lined
   - Access manway at top with platform, drain at bottom
   - Lifting lugs
   - Skid mounted
   - Air bleed vent/vacuum break
   - Internal header and lateral collection pipe system
   - Distribution baffle
   - Inlet and outlet flanges

4. Piping System Design

   - Liquid velocities (except backwash) - 10 ft./sec. (max)
   - Liquid velocity - backwash - 13 ft./sec. (max)
   - Material suitable for dilute acid and dilute caustic service
   - Manual valves - butterfly, gate
   - Measure flow rate into unit, total flow into unit
   - Sampling system to monitor pH and Fluoride
   - Control treatment system flow rate
   - Control treatment system pressure

C. <u>Quantity and Quality of Treated Water for Distribution</u>

1. Raw water flow rate- 1000 gpm (max). Treatment unit design. Flow rate 300 gpm each, or 600 gpm.

2. Treated water total flow - 97% raw water flow - 840,000 GPD.

3. Waste water - 3% raw water flow - 26,000 GPD.

4. Measure fluoride content of treated water.

5. Measure pH level of treated water. Include high and low pH alarms interlocked with raw water pump power supply; thereby plant will sound alarm and will shut down in the event of high or low pH. Include provision to flush system to waste in the event of high or low pH shut down. Manual start-up only after shutdown.

6. Incorporate provisions to lower raw water pH and raise treated water pH.

D. Regeneration and Neutralization

1. Regeneration material - 1% NaOH

   - Blend of 50% NaOH and softened raw water in "mixing T" at treatment unit

   - 50% NaOH procured directly from caustic manufacturer, delivered to plant in tank trucks

   - Provide 6000 gallon insulated caustic storage tank (horizontal) with manway, immersion heater (incl. controls) to maintain 70° F min., lifting lugs, vent w/overflow, fill piping, drain piping, level measurement capability and outlets to service.

2. Regeneration process

   - Flow rate through treatment unit - 2-1/2 gpm/ft.^{2} (max)

   - Residence time in treatment bed - 40 minutes (min)

   - Incorporate provision for upflow or downflow through bed

3. Regeneration Equipment

   - Chemical pump - Metering pumps with precision flow control. Corrosion resistant material - Interlock pump controls with well pump power supply so that chemical pump can't operate when pump is off. Pump mounted upon steel stand above Day Tank. Day Tank filled via gravity from Caustic Storage

   - Plug valves, check valves, pressure relief valves and back-pressure valves as required for total operational control and good maintenance.

   - Provide emergency shower and eyewash

4. Neutralization material - 0.04% H_2SO_4

- Blend of 93% H_2SO_4 and softened water in "mixing T" at treatment unit

- 93% H_2SO_4 procured directly from acid manufacturer, delivered to plant in tank trucks

- Provide 6000 gallon acid storage horizonizontal tank with manway, lifting lugs, vent w/overflow, fill piping, drain piping, level measurement capability and outlet to service

5. Neutralization process

   - Flow rate through treatment unit - 7 gpm/ft.^{2} (max)

   - Amount of acid rinse required - sufficient to adjust pH within acceptable pH limits 6.5 - 8.5

   - Incorporate provision for upflow or downflow through bed

6. Neutralization equipment

   - Chemical pumps - 2 Metering pumps with precision flow control. Corrosion resistant material. Interlock pump controls with well pump supply so that chemical pumps cannot operate when well pump is off. Pumps mounted upon steel stand above Day Tank. Day Tank filled via gravity from Acid Storage Tank.

   - Plug valves, check valves, pressure relief valves and back-pressure valves as required for total operational control and good maintenance.

7. - Zeolite softener complete with brine tank and automatic regeneration. Size softener to remove hardness ions from 300 gallons (min.) of raw water per cubic feet of activated alumina in individual treatment unit. Hardness level during pilot testing was 30 grains per gallon. Include manual isolation valves to employ softened water only during regeneration.

E. <u>Treatment Building</u>

1. Provide facility to house Treatment Units, Chemical Handling Systems, and Sampling System.

2. House operator's tools, supplies, records, etc.

3. House chemical test equipment with lab sink, counter and cabinets.

. <u>Abide by Applicable Portions of the Following Codes and Standards</u>

1. ASME Boiler & Pressure Vessel Code - Section VIII, Division 1
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3. AWWA
4. American Concrete Institute Building Code - 318
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The fluoride removal pilot test runs have demonstrated that a full scale fluoride removal water treatment plant with raw water pH adjustment, can reliably remove 1700 grains of fluoride per cubic foot of activated alumina. Operating treatment cost projection for the full scale plant is 15¢/1000 gallons. Capital cost estimate for the 1000 gpm treatment system is $270,000.

Interfering ions present in the raw water are competing fluoride for adsorption sites on the granular activated alumina surfaces. The interfering ions have been identified as T.O.C. Although the T.O.C. is easily removed during regeneration, its presence does reduce the fluoride removal capacity of the activated alumina to the above mentioned 1700 grains per cubic foot.

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1. Rubel and Hager, Inc., "Feasibility Study for the Removal of Excess Fluoride from Activated Carbon Effluent", The Deaprtment of the Army, Rocky Mountain Arsenal (Ref. #DAAA05-78-M-0914), ITARMS Project No. 1.05.15, September 30, 1978

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